PB-240 913

HAGER POND, MIDDLESEX COUNTY, MASSACHUSETTS

Pacific Northwest Environmental Research Laboratory

Prepared for:

National Environmental Research Center
Massachusetts Water Resources Commission
Massachusetts National Guard

February 1975

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16. ABSTRACT
Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivded according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
eutrophication lakes nutrients phosphorus nitrogen loading		05B 05C

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REPORT
ON
HAGER POND
MIDDLESEX COUNTY
MASSACHUSETTS
EPA REGION I
WORKING PAPER No. 220

WITH THE COOPERATION OF THE
MASSACHUSETTS WATER RESOURCES COMMISSION
AND THE
MASSACHUSETTS NATIONAL GUARD
FEBRUARY, 1975

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Massachusetts Division of Water Pollution Control for professional involvement and to the Massachusetts National Guard for conducting the tributary sampling phase of the Survey.

Thomas C. McMahon, Director, John R. Elwood, Supervisory Sanitary Engineer, Eben Chesebrough, Senior Chemist, and Peter A. Tennant, Senior Sanitary Engineer of the Massachusetts Division of Water Pollution Control provided invaluable lake documentation and counsel during the course of the Survey.

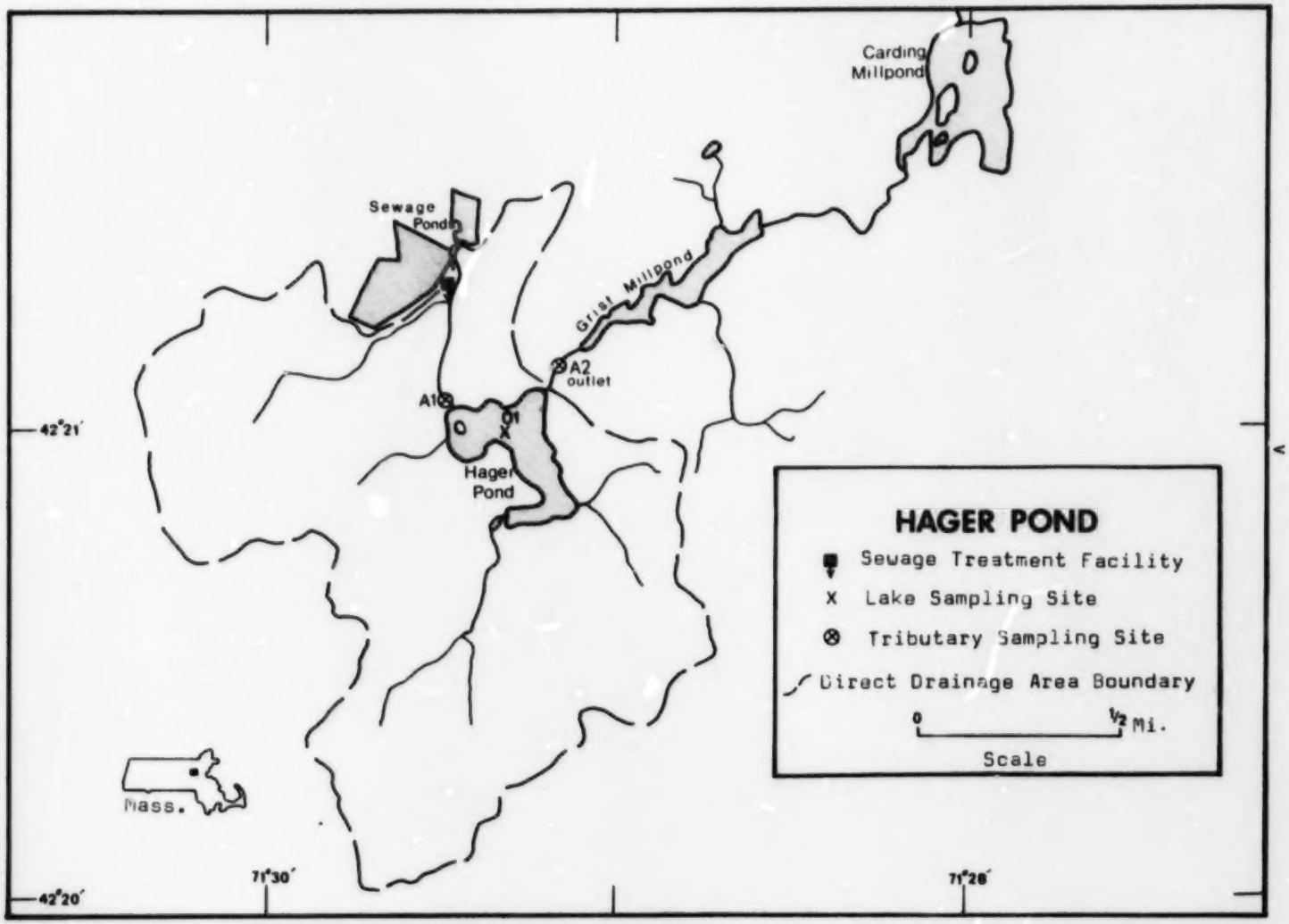
Major General Vahan Vartanian, the Adjutant General of Massachusetts, and Project Officer Major William Flaherty, who directed the volunteer efforts of the Massachusetts National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MASSACHUSETTS

LAKE NAME	COUNTY
Assabet-Concord River Impoundments	
Northboro	Worcester
Hudson	Middlesex
Maynard	Middlesex
Billerica	Middlesex
Hager Pond	Middlesex
Matfield Impoundment	Plymouth
Rochdale Pond	Worcester
Woods Pond	Berkshire


Carding Millpond
Sewage Ponds
Grist Millpond
A2 outlet
A1
01
Hager Pond
42°21'
42°20'
71°30'
71°28'
Mass.
HAGER POND
Sewage Treatment Facility
Lake Sampling Site
Tributary Sampling Site
Direct Drainage Area Boundary
0
½ Mi.
Scale

HAGER POND

STORET NO. 2502

I. CONCLUSIONS

A. Trophic Condition:

Hager Pond is a hypereutrophic impoundment which in recent years has been plagued by obnoxious algal blooms and periodic fish kills (Ketelle and Uttormark, 1971). Anaerobic conditions reportedly occur over approximately one-third of the deeper parts of the pond during about five months of the year (Anonymous, 1972). High phosphorus concentrations and extraordinarily high nitrogen levels result in tremendous algal growths. Exceptionally high chlorophyll a values (approaching 300 µg/l during the August sampling) and algal standing crop densities, ranging from 33,000 to 81,000 cells/ml, reflect the high nutrient loading rates to the pond and lend support to the hypereutrophic classification.

B. Rate-Limiting Nutrient:

There was a significant loss of nutrients in the algal assay sample between the time of collection and the beginning of the assay, and the results are not representative of conditions in the pond at the time the sample was taken. However, the levels of nutrients measured indicate that potentially Hager Pond had a high level of primary productivity at the time the sample was collected.

The pond data indicate phosphorus limitation at all sampling times.

C. Nutrient Controllability:

1. Point sources--During the sampling year, Hager Pond received a total phosphorus load at a rate over 140 times the rate proposed by Vollenweider as "dangerous"; i.e., a eutrophic rate (see page 12). Now, Hager Pond has a rather short hydraulic retention time of 24 days, and Vollenweider's model may not be applicable. Nonetheless, the trophic condition of the pond is evidence of excessive nutrient loads.

It is calculated that the Marlborough-Easterly wastewater treatment plant contributed about 99% of the total phosphorus load to Hager Pond during the sampling year. Presently, it is planned to expand the Marlborough-Easterly plant capacity and install nutrient removal equipment which will result in a higher quality effluent which should improve the trophic condition of the pond.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 25 acres.
2. Mean depth: 5 feet.
3. Maximum depth: 10 feet.
4. Volume: 125 acre-feet.
5. Mean hydraulic retention time: 24 days.

B. Tributary and Outlet:
(See Appendix A for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
Unnamed Brook (A-1)	0.9 mi^2	1.4 cfs
Minor tributaries & immediate drainage -	0.7 mi^2	1.2 cfs
Totals	1.6 mi^2	2.6 cfs

2. Outlet -

Unnamed Brook (A-2)	1.7 mi^2**	2.6 cfs

C. Precipitation***:

1. Year of sampling: 56.9 inches.
2. Mean annual: 43.3 inches.

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† Anonymous, 1972.
* Drainage areas are accurate within ±1%; gaged mean daily, monthly, and normalized monthly flows are accurate within ±15%; and ungaged mean daily, monthly, and normalized flows are accurate within ±20%.
** Includes area of lake.
*** See Working Paper No. 1, "Survey Methods, 1972".

III. LAKE WATER QUALITY SUMMARY

Hager Pond was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at the single station on the pond (see map, page v). During each visit, a single depth-integrated (near bottom to surface) sample was collected for phytoplankton identification and enumeration, and a similar depth-integrated sample was collected for chlorophyll *a* analysis. During the last visit, a five-gallon depth-integrated sample was collected for algal assays. The maximum depth sampled was four feet.

The results obtained are presented in full in Appendix B, and the data for the fall sampling period, when the pond essentially was well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix B.

A. Physical and chemical characteristics:

Parameter	Minimum	Mean	Median	Maximum
		FALL VALUES (10/06/72)		
Temperature (Cent.)	15.5	15.5	15.5	15.5
Dissolved oxygen (mg/l)	9.0	9.0	9.0	9.0
Conductivity (μmhos)	610	610	610	610
pH (units)	6.6	6.7	6.7	6.8
Alkalinity (mg/l)	51	57	57	62
Total P (mg/l)	2.330	2.405	2.405	2.480
Dissolved P (mg/l)	1.470	1.495	1.495	1.520
NO_2 + NO_3 (mg/l)	0.440	0.465	0.465	0.490
Ammonia (mg/l)	21.500	24.050	24.050	26.600
		ALL VALUES		
Secchi disc (inches)	12	17	18	20

B. Biological charateristics:

1. Phytoplankton* -

Sampling Date	Dominant Genera	Number per ml
08/04/72	1. Pediastrum	54,182
	2. Scenedesmus	12,545
	3. Tetraëdron	10,727
	4. Raphidiopsis	909
	5. Dinobryon	909
	Other genera	2,364
	Total	81,636
10/06/72	1. Scenedesmus	22,256
	2. Pediastrum	7,068
	3. Cyclotella	2,481
	4. Dinobryon	301
	5. Navicula	226
	Other genera	751
	Total	33,083

2. Chlorophyll a -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll a (µg/l)
05/30/72	01	163.6
08/04/72	01	297.7
10/06/72	01	134.1

* The June sample was lost in shipment.

C. Limiting Nutrient Study:

There was a significant loss of nutrients in the assay sample between the time of collection and the beginning of the assay, and the results are not indicative of conditions in the pond at the time the sample was taken. However, the levels of nutrients indicate that potentially Hager Pond had a high level of primary productivity.

The pond data indicate phosphorus limitation at all sampling times (the N/P ratios were 15/1 or greater and phosphorus limitation would be expected).

IV. NUTRIENT LOADINGS
(See Appendix C for data)

For the determination of nutrient loadings, the Massachusetts National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of March and April, when two samples were collected, and in November when samples were omitted. Sampling was begun in September, 1972, and was completed in August, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Massachusetts District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in $lbs/mi^2/year$, in tributaries to nearby Maynard Impoundment at stations B-1 and C-1 and multiplying the means by the ZZ area in mi^2.

The operator of the Marlborough-Easterly wastewater treatment plant provided monthly effluent samples and corresponding flow data.

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* See Working Paper No. 1.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (mgd)	Receiving Water
Marlborough-Easterly	15,000	trickling filter + ponds	2.612	Hager Pond

2. Known industrial - None

* Cady, 1973.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Unnamed Brook (A-1)	140	0.5
b. Minor tributaries & immediate drainage (non-point load) -	110	0.4
c. Known municipal STP's -		
Marlborough-Easterly	28,620	99.1
d. Septic tanks - Unknown	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	<10	<0.1
Total	28,870	100.0

2. Outputs -

Lake outlet - Unnamed Brook (A-2) 7,740

3. Net annual P accumulation - 21,130 pounds

* See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/ yr	% of total
a. Tributaries (non-point load) -		
Unnamed Brook (A-1)	4,400	3.4
b. Minor tributaries & immediate drainage (non-point load) -	3,450	2.7
c. Known municipal STP's -		
Marlborough-Easterly	120,140	93.9
d. Septic tanks - Unknown	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	10	<0.1
Total	128,000	100.0

2. Outputs -

Lake outlet - Unnamed Brook (A-2) 59,030

3. Net annual N accumulation - 68,970 pounds

* See Working Paper No. 1.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs P/mi^2/yr	lbs N/mi^2/yr
Unnamed Brook (A-1)	157	4,929

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with very short hydraulic retention times.

Units	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
lbs/acre/yr	1,154.8	845.3	5,120.0	2,758.8
grams/m^2/yr	129.43	94.73	573.9	309.2

Vollenweider loading rates for phosphorus (g/m^2/yr) based on mean depth and mean hydraulic retention time of Hager Pond:

"Dangerous" (eutrophic rate)	0.92
"Permissible" (oligotrophic rate)	0.46

V. LITERATURE REVIEWED

Anonymous, 1972. Survey questionnaire. MA Water Res. Comm., Boston.

Cady, Robert M., 1973. Treatment plant questionnaire (Marlboro Easterly STP). MA Div. Water Poll. Contr., Boston.

Ketelle, Martha J., and Paul D. Uttormark, 1971. Problem lakes in the United States. EPA Water Poll. Contr. Res. Serv., Proj. #16010 EHR.

Vollenweider, Richard A. (in press). Input-output models. Schweiz. Z. Hydrol.

VII. APPENDICES

APPENDIX A

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MASSACHUSETTS 11/26/74

LAKE CODE 2502 HAGER POND

TOTAL DRAINAGE AREA OF LAKE 1.71

TRIBUTARY	SUB-DRAINAGE AREA	NORMALIZED FLOWS JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2502A1	0.94	1.61	1.79	3.21	3.04	1.92	1.03	0.47	0.50	0.53	0.62	1.17	1.33	1.43
2502A2	1.71	2.94	3.25	5.83	5.52	3.49	1.88	0.86	0.90	0.96	1.12	2.12	2.41	2.60
2502ZZ	0.77	1.32	1.46	2.63	2.49	1.57	0.85	0.39	0.41	0.43	0.50	0.95	1.09	1.17

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 1.71
SUM OF SUB-DRAINAGE AREAS = 1.71
TOTAL FLOW IN = 31.31
TOTAL FLOW OUT = 31.28

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2502A1	9	72	0.46	9	0.57				
	10	72	0.72	14	0.65				
	11	72	2.89						
	12	72	3.32	9	5.11				
	1	73	2.90	13	1.55				
	2	73	2.92	10	3.08				
	3	73	2.51	10	5.25	23	2.59		
	4	73	3.95	14	3.29	28	3.22		
	5	73	2.13	12	2.53				
	6	73	1.36	9	1.00				
	7	73	1.57	14	1.44				
	8	73	0.85	26	0.41				
2502A2	9	72	0.84	9	1.03				
	10	72	1.31	14	1.18				
	11	72	5.24						
	12	72	6.07	9	9.30				
	1	73	5.29	13	2.82				
	2	73	5.30	10	5.61				
	3	73	4.56	10	9.56	23	4.72		
	4	73	7.18	14	5.98	28	5.86		
	5	73	3.47	12	4.60				
	6	73	2.48	9	1.81				
	7	73	2.86	14	2.62				
	8	73	1.55	26	0.74				
2502ZZ	9	72	0.38						
	10	72	0.59						
	11	72	2.36						
	12	72	2.72						
	1	73	2.38						
	2	73	2.38						
	3	73	2.06						
	4	73	3.74						
	5	73	1.74						
	6	73	1.13						
	7	73	1.28						
	8	73	0.70						

APPENDIX B

PHYSICAL and CHEMICAL DATA

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STORET RETRIEVAL DATE 74/11/26

250201
42 21 00.0 071 29 17.0
HAGER POND
25045 MASSACHUSETTS

11ENGALES
J

2111202
0004 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/05/30	11 33	0000	20.5	11.8	12	340	6.60	13	0.600	4.900	0.660	0.326
	11 33	0002	16.4	7.2		360	7.20	17	0.400	6.200	1.080	0.465
72/08/04	13 40	0000			18	420	7.62	23	0.310	0.220	0.685	0.164
	13 40	0004	24.3	9.4		417	6.95	27	0.610	7.500	1.970	0.500
72/10/06	13 35	0000			20	610	6.65	62	0.440	21.500	2.330	1.520
	13 35	0003	15.5	9.0		610	6.75	51	0.490	26.600	2.480	1.470

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/05/30	11 33	0000	163.6J
72/08/04	13 40	0000	297.7J
72/10/06	13 35	0000	134.1J

J VALUE KNOWN TO BE IN ERROR

APPENDIX C

TRIBUTARY and WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 74/11/26

2502A1 LS2502A1
42 21 00.0 071 29 30.0
NO NAME
25045 7.5 FRAMINGHAM
I/HAGER POND
US 20 BRDG BELO MARLBORO STP
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/09/09	10 00		0.300	24.250	21.000		2.100
72/10/14	14 35		0.490	22.500	20.000	0.631	0.650
72/12/09	08 15		0.650	11.000	6.720	0.256	0.610
73/01/13	09 00		0.330	16.800	13.100	1.230	2.900
73/02/10	09 30		0.250		5.750	1.100	2.200
73/03/10	07 30		0.220	13.000	10.000	0.240	0.670
73/03/23	07 35		0.330	13.000	11.800	0.920	2.400
73/04/14	07 35		0.350		8.500	0.560	1.450
73/04/28	07 10		0.230	13.000	9.700	1.130	2.000
73/05/12	07 25		0.190	14.900	11.000	1.470	2.300
73/06/09	07 35		0.160	19.900	15.600	2.500	3.850
73/07/14	07 35		0.920	16.800	16.800	1.500	2.500
73/08/26	11 10		0.231	25.500	22.500		3.700

STORET RETRIEVAL DATE 74/11/26

2502A2 LS2502A2
42 21 00.0 071 29 00.0
POND OUTLET TO GRISTMILL PD
25 7.5 FRAMINGHAM
O/HAGERS POND
US 20 BRDG
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/09/09	10 15		0.675	12.500	11.400		1.900
72/10/14	14 45		0.570	8.700	2.500	0.470	0.500
72/12/09	08 20		0.330	11.000	1.800	0.360	0.560
73/01/13	09 00		0.315	11.800	9.400	0.820	1.800
73/02/10	10 00		0.380		8.812	1.280	1.570
73/03/10	07 30		0.176	7.800	6.100	0.273	0.610
73/03/23	07 30		0.190	9.450	7.050	0.640	1.050
73/04/14	07 30		0.270		4.500	0.460	0.800
73/04/28	07 00		0.240	10.400	6.600	0.960	1.650
73/05/12	07 30		0.340	11.000	7.400	1.200	1.700
73/06/09	07 30		0.260	11.800	8.300	2.200	2.700
73/07/14	07 30		0.050	8.700	5.600	0.980	1.500
73/08/26	11 00		0.510	19.500	7.100	1.900	2.600

STORET RETRIEVAL DATE 74/11/27

250250 TF250250 P015000
42 21 30.0 071 29 30.0
MARLBORO EASTERLY
25045 7.5 FRAMINGHAM
T/HAGER POND
UNNAMED STREAM
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/01/02	08 00								
CP(T)-			0.430	9.450	4.600	0.620	1.790	3.580	3.260
73/01/02	16 00								
73/03/16	08 00								
CP(T)-			0.035	21.000	12.100	1.400	3.200	2.630	2.780
73/03/16	17 00								
73/07/02	08 00								
CP(T)-			0.860	7.000	4.800	2.010	2.600	3.060	2.450
73/07/02	08 00								
73/08/30	08 00								
CP(T)-				24.000		2.300	3.400	1.640	
73/08/31	08 00								
73/09/25	08 00								
CP(T)-			0.[illegible]00	18.400	14.700	1.980	2.900	1.880	1.500
73/09/26	08 00								
73/10/11	08 00								
CP(T)-			0.262	22.000	22.000	1.540	3.000	1.480	1.550
73/10/12	08 00								
74/01/04	08 00								
CP(T)-			0.240	18.500	15.000	5.520	6.200	2.970	2.980
74/01/05	08 00								
74/02/19	08 00								
CP(T)-			0.560	18.500	9.700	6.100	6.700	2.330	2.980
74/02/20	08 00								
74/04/16	08 00								
CP(T)-			1.840	10.000	6.800	2.500	3.000	3.800	3.400
74/04/17	08 00								